Lifecycle Energy Management in the Tohoku Electric Power Company Head Office Building

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Takeshi Kondo (NIKKEN SEKKEI Research Institute)
Shinji Okuda (Tohoku Electric Power)
Acknowledgements

Joint implementation
(organization of life cycle energy management)

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<thead>
<tr>
<th>Building Manager</th>
<th>Tohoku electric power co., Inc</th>
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<td>Shinji Okuda, Tokuro Kurihara, Akinori Yokosawa</td>
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<tr>
<th>Owner and Building operator</th>
<th>Higashi Nihon Kougyo co., Inc</th>
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<td>Shuji Shikano, Minoru Sasaki</td>
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<th>Designer</th>
<th>Nikken Sekkei Ltd.</th>
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<td>Keiji Yamada, Kaoru Watanabe</td>
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<th>Constructer</th>
<th>Yurtec Corporation</th>
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<td>Hitoshi Akai, Shinya Mouri</td>
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<th>Commissioning Provider</th>
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Proceedings of the 14th International Conference for Enhanced Building Operations, Beijing, China, September 14-17, 2014
Outline and Scheme of the Project

| 1. | This building was opened in 2002, in the earthquake disaster area. |
| 2. | Total floor area is 64,000m². |
| 3. | Central function operating 24 hours was introduced to stabilize power supply for the 7 Tohoku prefectures in Japan. |
| 4. | The main theme of the project |
|     | Ecologically friendly |
|     | Top-class energy-saving |
|     | Top-class power load leveling |

SETSUDEN 節電
What is “Lifecycle energy management”? 

#1 Defined the energy performance target values in the OPR.
OPR: Owner’s Project Requirements (A type of documents in commissioning process)

#2 Check the design methods to ensure the OPR are concretely specified.

#3 Check the construction to ensure the OPR are reliably performed.

#4 Verify the realized performance to meet the OPR, and the suitable improvements are planned based on the operating status.

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**Fig 4: The construction process with Lifecycle energy management**

- **#1 Planning**
  - CO2 Emission
  - Energy Cost
  - Standard
  - Target
  - Check

- **#2 Design**
  - Information

- **#3 Construction**
  - Information
  - Check

- **#4 Operation**
  - Information
  - Check

- **Owner (Development)**
  - Planner
  - Designer
  - Supervisor
  - Constructor

- **Owner (Operation)**
  - Operation & Maintenance

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Proceedings of the 14th International Conference for Enhanced Building Operations (ESL-IC-14-09-07)
Diagram of thorough approach to a “SETSUDEN” building

Maximum Power Demand

#1 The building is designed with standard specifications: 80W/m²
#2 The building is designed with energy-saving spec.: 50W/m²
#3 The building is designed with Load leveling spec.: 40W/m²

Fig 5. Maximum power demand by standard usage

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Achieving top-class power load leveling

By applying lifecycle energy management, we succeeded in reducing maximum power demand to less than 50% for 10 years in succession.

Fig 8. Comparison between Maximum power demand (2004-2011)
Achieving top-class energy-saving

• Set the target value as 1,600 MJ/(m²·yr) (1,518 kBTU/(m²·yr))
• The energy consumption amount was reduced each year.

Fig 9. Changes in units annual energy consumption (2002-2011)
The Planning phase: Creation of the OPR

• Lifecycle energy management starts with setting target values that take into account client needs and creating the OPR.

OPR: Owner’s Project Requirements (A type of documents in commissioning process)

"Achieving top-class power load leveling"

The maximum power demand \( \leq 40\text{W/m}^2 \)
Equivalent to 50% to that of a building with standard Spec.

"Realizing an ecologically friendly building"

Annual primary energy consumption \( \leq 1,100\text{MJ/(m}^2\text{.yr)} \)
\( (1,043\text{kBTU/(m}^2\text{.yr)} \)
Equivalent to 50% of that of a building with standard Spec.

• The target values stated above were determined through negotiations with the client on building usage conditions.
**The design phase:** Concrete Specification of methods

**Energy-saving**
- Architectural schemes
- Environmentally complicit
- High-efficiency equipment
- Eliminating waste energy

**Load leveling**
- Thermal storage

**Effect verification**
- BEMS
- Analysis performance

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**Contents in Office Floor**
- Sun shade
- High Insulation
- Natural lighting
- Natural ventilation
- VAV-VWV control
- Motion detector system
- Mass Thermal Storage

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**Typical floor measurement (20th floor)**

**Fig 10. Specification of methods**

- Hot-water-storage Electric water heater
- Ice Thermal Storage (9,000RT·h)
- Hot Water Thermal Storage (2,000 m³)
- Rain Storage
- Well
- Foliage & Wind
- PV
- BEMS
- Office
The design phase: Window area schemes

Increase the effects of natural lighting

- The height of the ceiling near windows was increased and a light shelf was created.
- Direct sunlight is screened, enabling diffused light to be taken in.
- On sunny days, it is possible to secure more than 500 lx using only natural lighting.

Problem

The increase in thermal load as the size of the window increases

Reduction of heat load

- Air flow windows
- Natural ventilation
- Night purge

Refreshment

- Retracting Blind

Feeling refreshed while looking at the mountain ranges around Sendai.

Fig 11. Cross-section of the window area
The construction phase: Verification of the AFW

- The construction was performed after verifying the schemes of the design phase.
- To verify the performance of the AFW (air flow window) through experiments.
- The insulation performance was high resolution in a comfortable work environment.

Veriﬁcation of AWF in an environmental test room

**Fig 12. Comparison between the glass surface temperature of the indoor side of the AFW.**

- Test condition
  - Outdoor temp. -3 °C (27°F)
  - Indoor temp. 22 °C (72°F)

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<th>Condition</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
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</thead>
<tbody>
<tr>
<td>a) Ventilation volume 0 CMH</td>
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<tr>
<td>b) Ventilation volume 50 CMH</td>
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Uncomfortable

High insulation & Comfortable

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The operating phase: Organization and Purpose

**The completion of construction**

**1st STEP**

- **Organization**
  - “The meeting for verifying energy conservation”
  - the Designers, the building owner, the employees
  - the Maintenance operators, the constructors
- **Main purpose**
  - To verify the effects expected the schemes in the design

**2nd STEP**

- **Organization**
  - “The meeting for maintenance of the building”
  - the Maintenance operators, the constructors
- **Main purpose**
  - To verify the actual operating status and discussion of problems

**3rd STEP**

- **Organization**
  - “The energy conservation project team”
  - the building owner, the employees
  - the Maintenance operators, the constructors
- **Main purpose**
  - To thorough the maximum power demand reduction
The operating phase: 

To verify the effects expected the schemes in the design Large-temperature-differential air-conditioning systems

It was verified that the chilled water temperature differential of more than 10deg was secured most of the time.

Fig 13. Frequency of difference of chilled water temperature

KWh = \( k \times \frac{Q}{\Delta t} \times \frac{P}{\eta} \)

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To Verify the actual status of performance targets stated in the OPR

Maximum power demand for power load levering

It was verified that the power load leveling target of units maximum power demand of 40W/m$^2$ was reached.

Fig 14. Duration curve of power demand (2002/7 ~ 2003/6)
To Verify the actual status of performance targets stated in the OPR

Annual primary energy consumption for ecological building

It was verified that the targets other than the annual primary energy consumption amount had already been satisfied, and the initial validation of the performance period was concluded.

The efforts up until this point were honored with the Energy Conservation Architecture Award, and the Institute Chairman's Award of IBEC (Institute for Building Environment and Energy Conservation).
To verify the actual operating status and discussion of problems

Natural Ventilation system

There are 2 points for adjusting the natural ventilation system

1) Taking into the working conditions for employees
2) Adjusting the natural ventilation operation to a longer period of time

After 2005, the natural ventilation operating time was changed 7 times since 2004.

Operating Conditions

• Outdoor Temp

Maximum Set point
Before: 24°C (75°F) (fix)
After: 22°C (72°F) (fix)

Minimum Set point
Before: 15°C (59°F) (fix)
After: 1~14°C (manual) (34~57°F)

Fig 15. Operating time of natural ventilation
The result achieved was a 39% reduction of maximum power demand through the hard work by the Energy Conservation Project Team.

**Fig 16. Comparison between maximum power demand (2010 vs 2011)**
### Thorough Maximum power demand reduction

#### Type | Method
---|---
Air conditioning | Room Temp ↑
| AC Period reduced
| AC Area limited
Illumination | Illumination level ↓
| Period reduced
OA equipment | Energy-saving mode
| Unplugging
Others | Restrictions on the use of water heaters
| vending machines reduced
| Restrictions on EV usage
| Escalators were stopped
| Restrictions on automatic door usage

The operating phase:

1. **1st STEP**
2. **2nd STEP**
3. **3rd STEP**

**Fig 17. Contents of power demand reduction**

The Illumination and the Air conditioning in this building was greatly reduced.
Conclusion

• **Power load leveling & Energy saving** is important for an effective cost-saving and the electric grid stability.

• In Japan, we call it “**SETSUDEN”**. 節電

• To realize a “**SETSUDEN”** building, we implemented a lifecycle energy management.

• We have achieved a “**SETSUDEN”** building for **10 years** with the cooperation of the stakeholders.

• **The coordinated functions and actions of the building and its employees** can improve the energy performance of a building greatly.

• We hope our efforts in this challenge will serve as a valuable reference for you.